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FEASIBILITY STUDY FOR THE APPLICATION OF AN EASY-FIX METHOD FOR REDEPLOYING DAMAGED ISO TACTICAL SHELTERS

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This report documents a program which was conducted to study the feasibility of using an "Easy-Fix" system to redeploy structurally damaged ISO tactical shelters. This system could be used to evacuate structurally damaged non-operational tactical shelters using external helicopter airlift capabilities. Various concepts and material systems were evaluated with respect to size, weight, and cost.

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FEASIBILITY STUDY FOR THE APPLICATION OF AN EASY-FIX METHOD FOR REDEPLOYING DAMAGED ISO TACTICAL SHELTERS

PREFACE

The effort documented in this report was performed by the University of Dayton Research Institute (UDRI), Dayton, Ohio, under Contract F33615-85-C-5094, "Technical Support for Tactical Shelters," for the Materials Laboratory, Air Force Wright Aeronautical Laboratories, Wright-Patterson Air Force Base, Ohio. Air Force administrative and technical direction was provided by Mr. Robert Urzi, AFWAL/MLSE.

The work described herein was conducted during the period January 1986 to February 1987. Project supervision was provided through the Materials Engineering Division of the University of Dayton Research Institute, with Mr. Dennis Gerdeman as supervisor and Mr. D. Robert Askins as Project Engineer during the overall activities. Technical effort was accomplished by Mr. D. R. Bowman, Applied Mechanics Group, Aerospace Mechanics Division.

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1.0 BACKGROUND/INTRODUCTION

Tactical shelters are susceptible to a variety of types of in-service damage. This can result from battle damage, handling/transport damage, and environmental damage, and can be of a structural or functional nature. Structural damage consists of damage of sufficient extent to walls, roof, floor, or frame that transportability of the shelter is jeopardized. EASY-FIX is a method for providing the means to evacuate structurally damaged, non-operational tactical shelters using external airlift capabilities.

The results of the feasibility study reported herein consist of a preliminary investigation to define structural concepts, material systems, and assembly procedures relative to the stated objectives. The concepts were evaluated with respect to size, weight, and cost. The results are summarized and conclusions and recommendations made.

2.0 PREMISES AND GUIDELINES

Guidelines used for the ISO EASY-FIX feasibility study are listed below.

- EASY-FIX shelter evacuation will be effected using helicopter airlift with Class 1 slinging provisions per MIL-STD-209F.
- The ISO shelter will not be transported in the expanded mode.
- Shelter air conditioning units will be discarded or pulled into the shelter prior to implementation of EASY-FIX.
- Shelter armor will be removed before effecting EASY-FIX, and will not be in place during the EASY-FIX evacuation.
- Any damaged shelter to which EASY-FIX is applied is no longer a functionally operational shelter, and upon

application there will be no entry into or egress from the shelter.

- No modification to existing shelters for attachment of EASY-FIX structural components will be made.
- Available field personnel will be assumed to possess no specialized mechanical skills or knowledge for evaluating structural integrity.
- There will be no electrical power at the shelter site.
- No special or exotic tools will be required to effect EASY-FIX.
- EASY-FIX concept will be capable of being effected by two persons in one eight-hour period.
- Materials, tools, and capability for making localized structural repairs is not a part of the EASY-FIX concept.
- The weight of the shelter and its contents are assumed to be uniformly distributed over the floor area of the shelter.
- The weight of the individual EASY-FIX structural components shall not exceed 120 pounds to facilitate two-person handling.
- The weight of all EASY-FIX structural members, fittings, and hardware shall not exceed ten percent of the shelter maximum shipping weight.
- The ISO shelter maximum shipping weight is taken as 20,000 pounds.
- EASY-FIX will be designed to be stored with the shelter or with a shelter support group.

3.0 STRUCTURAL CONCEPTS

A number of structural concepts were considered, some of which made use of the existing shelter structural members and lifting "eye" bolts. These approaches, however, had inherent disadvantages that are not compatible with the stated premises in Paragraph 2.0. The most important of these disadvantages are:

(1) A detailed assessment of the structural integrity of individual shelter components by on-site personnel is required,

(2) EASY-FIX structural members must be integrated into the undamaged shelter structure through special fittings and attachments,

(3) Bending stresses could be introduced into the EASY-FIX members where attach points, lifting eye, and truss-element force vectors could not be constrained to intersect at a common point,and

(4) System complexity becomes excessive.

Based on these considerations the concept depicted in Figure 1 was selected as being the most simple, versatile, and easy to effect. Structurally, the system reacts the applied loads as a truss. The tubular members form an independent framework at the top of the shelter and react the compressive loads. Tension cables (or rods) are used to transfer the loads resulting from the shelter weight into the tubular framework corner fittings. These cables will attach to corner fittings at the shelter base frame structure. The number of cables and the attach point location along the base frame structure could be varied in accordance with the severity and location of damage to the shelter; however, the kit should be kept as simple as possible to avoid confusion.

If the shelter base frame structure and floor system are severely damaged, additional tubular members and/or cables could be passed trough the fork lift tine openings or under the shelter base. Thus, this concept consists of a basket with a stiff rim

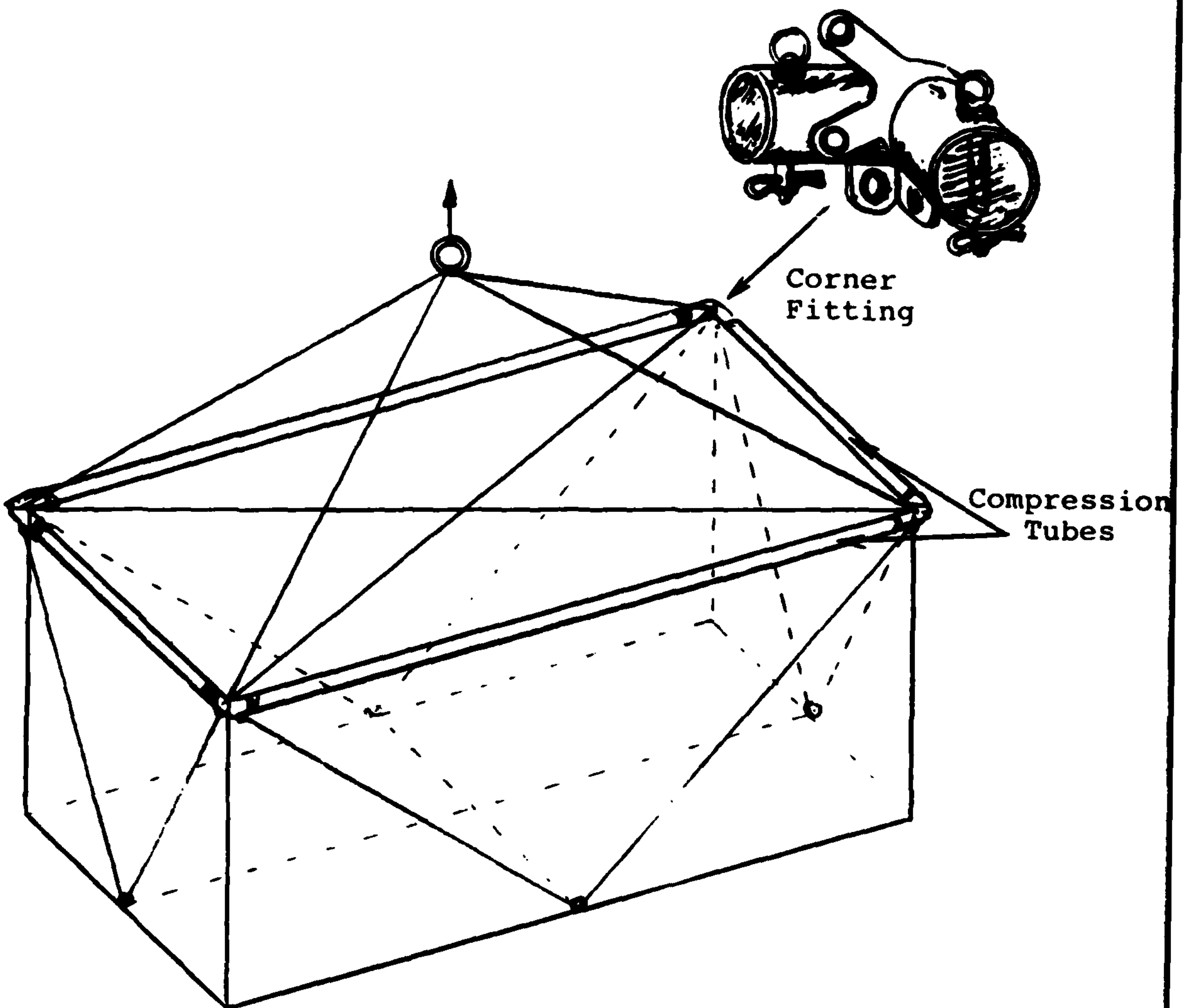

Figure 1. EASY-FIX Concept.

at the top that can be used to transport a shelter with varying degrees of damage.

Provisions for helicopter airlift will be similar to those used for the basic shelter. The only difference will be the use of lift rings on the tubular framework corner fittings instead of the shelter lift rings. For stability in the plane of the tubular frame, tension cables or rods connecting the diagonal corners will be installed. Vertical pins will be used to connect the tubular framework corner elbows to the straight tubular frame members. This will prevent out-of-plane warping due to rotation of the tubular frame corner members.

The EASY-FIX concepts provided herein are dependent on access underneath the shelter for placement of support cables or straps to complete the bottom of the basket. If corner jacks are not standard equipment with the ISO shelters, EASY-FIX kits would need to include them, or an alternative would be to include toe jacks for lifting at the forklift hole locations.

Design Loads

The design loads for helicopter airlift are defined in Paragraph 5.1.1.1 of MIL-STD-209F. For equipment weighing less than 20,000 pounds, the working load is equal to the maximum shipping weight multiplied by 3.2.* All slinging components, including the connection and structural members, are required to withstand their proportionate share of this working load without permanent deformation. In addition, they are required to have an ultimate strength not less than 1.5 times the working load.

The loads for an assumed worst case loading condition are depicted in Figure 2. The sling apex is over the center of gravity (assumed to be the geometric center of the shelter). The

*Applies to equipment with a maximum shipping weight to maximum projected frontal area ≥ 60 lbs/ft^2. For the shelter under consideration, this ratio equals 20,000/(20x8) = 125 lbs/ft^2.

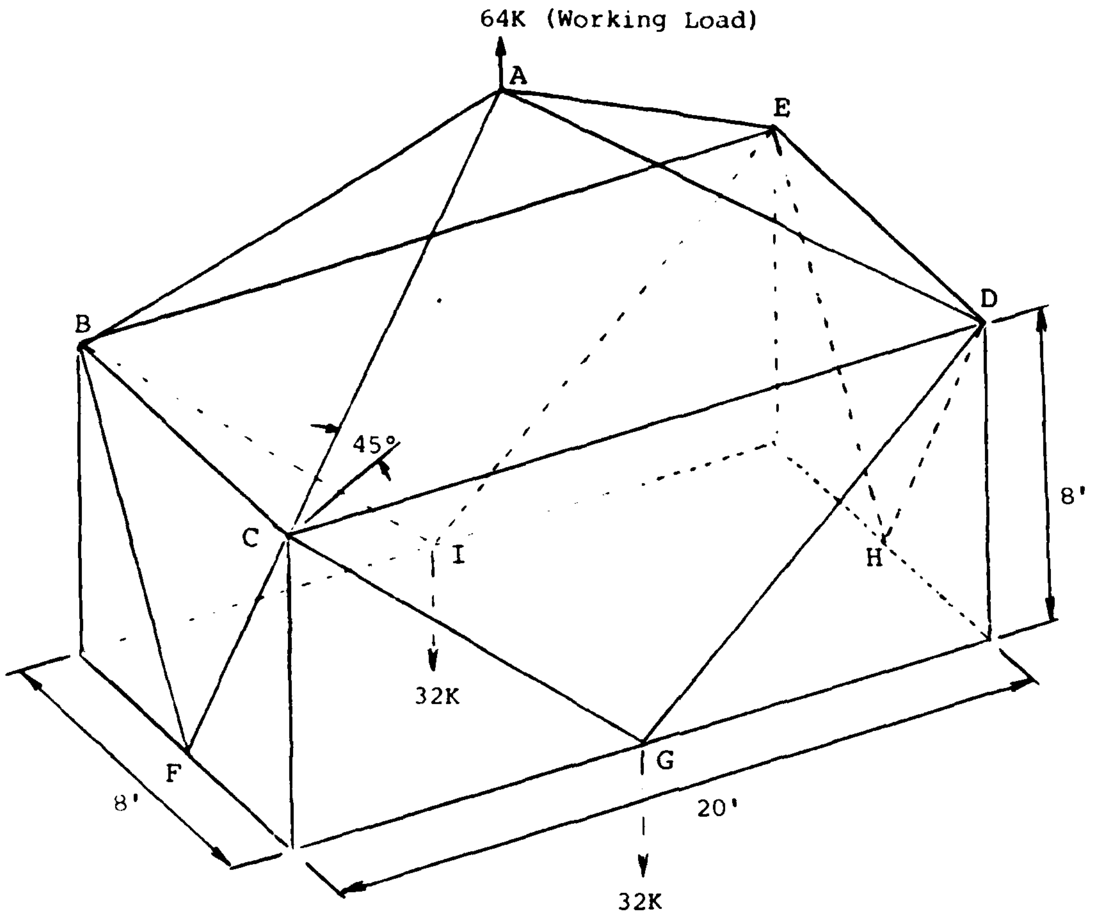

Figure 2. EASY-FIX Loads Diagram.

true angle of each sling leg is taken as 45 degrees from the vertical (the maximum angle permitted by MIL-STD-209F). The total shelter weight is conservatively assumed to be supported by cables attached to the center of the long side of the shelter.

This arrangement results in the most critical buckling load for the 20 foot long tubular compression members. The equivalent static limit design load (working load) for the EASY-FIX system is

$$P_{limit} = 3.2 \times 20{,}000 = 64{,}000 \text{ lb}$$

The corresponding equivalent static ultimate design load is

$$P_{ult} = 3.2 \times 1.5 \times 20{,}000 = 96{,}000 \text{ lb}$$

The working loads are shown in Figure 3. The working and ultimate design loads for the EASY-FIX components are summarized in Table 1.

4.0 MATERIAL SYSTEMS

Four representative material systems for the tubular compression members have been selected for evaluating the feasibility of the EASY-FIX concept. They are A-36 steel, 6061-T6 aluminum alloy, DWAL 20 (a SIC/6061-T6 metal matrix composite produced by DWA Composite Specialties, Inc.), and a high modulus GR/EP system. These systems are not exhaustive of material system possibilities. However, they cover a broad range with respect to weight and cost and provide a good basis for evaluating feasibility.

The EASY-FIX system tension members could be steel, Kevlar, nylon, or fiberglass cable or rod.

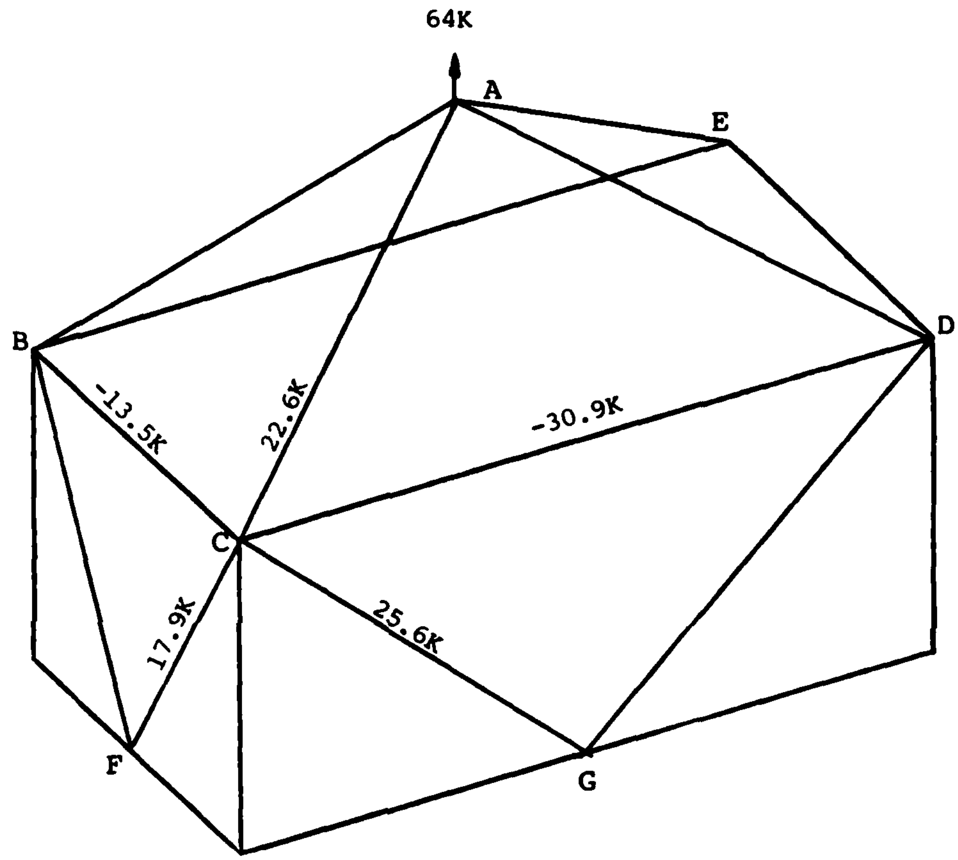

Figure 3. Working Loads Summary.

TABLE 1

DESIGN LOADS

Member	Working Load* (lbs)	Minimum Safety Factor Required	Ultimate Load (lbs)
AB,AC,AD, AE	22,600	5	113,100
BC, DE	-13,900	1.5	-20,900
BE,CD	-30,900	1.5	-46,300
BF,CF,DH, EH	17,900	5	89,400
CG, DG, BI, EI	25,600	5	128,100

*Working load is equal to maximum shipping weight multiplied by 3.2.

5.0 STRUCTURAL EVALUATION

Since the 20 foot long tubular compression members will fail catastrophically when the buckling load is reached, they will be designed using the Euler buckling formula for long columns:

$$P_{cr} = \frac{\pi^2 EI}{\ell^2}$$

From the loads analysis, P_{cr} = 46,300 lbs for the 20 foot long tubular compression members. Solving Euler's equation for the required stiffness gives

$$(EI)_{req'd} = \frac{P_{cr}\,\ell^2}{\pi^2}$$

Using this equation and assuming the members to be thin walled cylindrical tubes yields the results summarized in Table 2. Although for this study the compression tubes are designed strictly as columns, it is possible that eccentricity of the connections at the corner fittings would cause the tubes to carry some bending moment. Therefore, for a production design, the stiffness of the tubes should be increased to provide a safety factor against bending in addition to compression.

6.0 SYSTEM WEIGHT

Some perturbation about the cylindrical tube sizes listed in Table 2 would be required for weight optimization of a given material system. However, the weights shown are representative for each material system, and reflects the weight differences to be expected as a function of material system.

Table 2
ISO Tactical Shelter Easy-Fix Compression Tube Evaluation

Material System	E_x (ksi)	σ_y (ksi)	I_{req} (in.^{4})	Dia. (in.)	t_{wall} (in.)	A (in.^{2})	I_{act} (in.^{4})	L/R	σ_{act} (ksi)	ρ (lb/in.^{3})	Weight (lb/ft)	Weight Total (pounds)	Cost ($/lb)	Total Cost ($)
A-36 Steel	30×10^3	36	9.00	6.0	0.188	3.42	14.47	117.	13.53	0.283	11.61	232.	0.45	104.
				7.0	0.094	2.03	12.29	97.5	22.8	0.283	6.89	138.		62.
6061-T6 Al	10×10^3	38	27.01	6.0	0.5	8.64	33.20	122.	5.36	0.100	10.37	207.	1.30-1.80	320.
				7.0	0.25	5.3	30.23	100.	8.73	0.1	6.36	127.2		200.
				8.0	0.156	3.85	29.62	86.5	12.02	0.1	4.62	92.4		145.
E-30 GR/EP	22×10^3	72	12.28	5.0	0.375	5.45	14.66	146.	8.49	0.06	3.92	78.5		4320.
70% 0°				6.0	0.188	3.42	14.47	117.	13.53	0.06	2.46	49.3	35.75	2710.
30% ±45°				7.0	0.125	2.70	15.96	98.7	17.14	0.06	1.94	38.9		2140.
DWAL 20	18.5×10^3	65.2	14.6	5.0	0.438	6.27	16.47	148.	7.38	0.09	6.77	135.		5060.
(30 V/O SIC/				6.0	0.25	4.52	18.7	118.	10.25	0.09	4.88	97.6	30-45	3660.
6061-T6 Al)				7.0	0.125	2.70	15.96	98.7	17.14	0.09	2.92	58.3		2190.

Note: $P_{critical}$(ultimate) = -46,300 pounds

L_e = 240 in.

Note that to meet the guideline of 120 pound maximum tube weight, wall thickness for a steel tube would have to be less than 0.10 inch. This would not be acceptable because the tube could be easily dented and structurally compromised. Therefore, steel compression tubes cannot be used without exceeding the individual tube weight limitation.

Minimal production cost projection data is available for the DWAL 20 and graphite/epoxy material systems. Best estimates were used to establish a cost range and the median cost was used to project the cost of a fabricated 20 foot long tubular member.

The tension cables (or rods) will be of steel, nylon, fiberglass, or Kevlar. They will be round or flat in cross-section. Based on the maximum ultimate cable loads shown in Table 1 it is anticipated that 1-1/8 to 1-3/8 inch diameter steel cable would be required. Nylon straps would probably be more weight efficient, however, detailed design/analysis of fittings and cables (size and material) was considered beyond the scope of this study.

A cursory analysis of the system weight was made to evaluate feasibility with respect to the study guideline of being less than ten percent of the shelter weight. The assumptions made and the results of the weight analysis are summarized in Table 3. The estimated total system weight for all materials is well within the guidelines for feasibility.

7.0 CONCLUSIONS

This investigation resulted in the definition of a structural concept that provides the potential for meeting the EASY-FIX evacuation objective within the constraints established by the study ground rules and guidelines.

Several material systems were evaluated and all, except steel, provide acceptable individual member and total system

TABLE 3

ISO EASY-FIX SYSTEM WEIGHT

Material System	Compression Tubes	Aluminum Corner Fittings	Nylon Tension Members	Cable Fittings & Miscellaneous	Total Weight
A-36 Steel* 7" tube	367	80	150	490	1087 lbs.
6061-T6 Aluminum 8" tube	259	80	150	490	979 lbs.
DWAL 20 (30 V/O SIC/ 6061-T6 Aluminum) 6-7" tube	207	80	150	490	927 lbs.
E-30 GR/EP 70% 0^{o}, 30% $\pm 45^{o}$ 6" tube	182	80	150	490	902 lbs.

*Note that the individual tube weight (see Table 2) exceeds the 120 pound guideline.

weights for the shelter under consideration. Consideration of longer and/or heavier shelters could alter this result.

The proposed concept is characterized by simplicity and versatility. Assembly is capable of being accomplished by two persons with no special training or tools required; however, the use of a third person would make erection of the compression tubes much easier.

No major problem areas with respect to implementing this system are expected. Details regarding fitting design, tension member location and attachment, and the optimum number of components for maximizing flexibility require further study. However, these considerations are not expected to affect the conclusion regarding feasibility.

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